

Table 4. Dissolved nutrient data summary for National Water-Quality Assessment Program wells nationwide and for springs in the Valley and Ridge Physiographic Province in the upper Tennessee River Basin

[N, nitrogen; P, phosphorus; units in milligrams per liter; <, indicates values less than the reporting limit]

Parameter	National study-unit survey wells				UTEN springs (35 samples)		
	Minimum	Median	Maximum	Number of samples	Minimum	Median	Maximum
Ammonia, as N	<0.015	0.024	2.70	1,820 ^b	<0.015	<0.015	0.078
Ammonia plus organic nitrogen, as N	<0.200	<0.200	5.50	910 ^a	<0.200	<0.200	1.50
Nitrate, as N	<0.050	0.395	6.60	1,823 ^b	0.091	1.16	2.17
Total phosphorus, as P	<0.010	0.020	2.20	911 ^a	<0.010	<0.010	0.054
Orthophosphate, as P	<0.010	0.0125	0.18	1,819 ^b	<0.010	<0.010	0.027

^a Data from 1993 to 1995 (Hitt, 1999)

^b Data from 1993 to 1999 (Tom Noland, U.S. Geological Survey, written commun., 2001)

that water issuing from springs generally interacts less with the aquifer, following more shallow flowpaths along fractures and solution openings (Adamski, 1997). Twenty-four springs in agricultural areas in Florida had nitrate values ranging from 2.7 to 10.6 mg/L with a median value of 5.4 mg/L (Katz and others, 1999). In Illinois, 10 karst springs in agricultural areas were sampled, and 39 of 40 samples exceeded background nitrate levels of 1.4 mg/L, however, none exceeded the MCL. Seven springs sampled in non-agricultural areas were all below background levels (Webb and others, 1997). In the UTEN Valley and Ridge, ground-water samples from 30 wells had a lower median nitrate concentration (0.59 mg/L) than the springs (1.16 mg/L) where the springs and wells were in a similar land-use setting (Hampson and others, 2000).

In the Valley and Ridge springs, concentrations of the reduced nitrogen species (ammonia and ammonia plus organic nitrogen) were less than 0.200 mg/L in samples from all sites except one spring, which had a concentration of 1.50 mg/L (table 4). Concentrations of reduced nitrogen species would be expected to be low in a karst setting because of relatively high levels of dissolved oxygen. The median dissolved oxygen concentration in the UTEN Valley and Ridge springs was 7.1 mg/L (table 3). The presence of ammonia in the ground water may be the result of urea or animal waste applied to agricultural fields, from ammonia used directly as fertilizer, or from other sources. Ammonia was detected at 5 sites with a maximum concentration of 0.078 mg/L, whereas the remaining 30 sites had concentrations less than 0.015 mg/L

(table 4). The median concentrations of ammonia for the UTEN Valley and Ridge springs was less than the median concentration in ground water from wells for other NAWQA aquifer studies (table 4).

Phosphorus is an essential nutrient that can be found in fertilizers, manures, detergents, and atmospheric deposition (Likens and Bormann, 1995). Phosphorus is a common element in igneous rock and sediments, but concentrations present in solution in natural water are normally no more than a few tenths of a milligram per liter (Hem, 1985). Phosphorus is less mobile than nitrogen in the subsurface and tends to sorb to soil particles and soil organic matter. Total phosphorus was detected in only 6 of the 35 samples collected. Concentrations of total phosphorus ranged from less than 0.010 mg/L to 0.054 mg/L with a median of less than 0.010 mg/L. Orthophosphate was detected in 9 of the 35 samples, and concentrations ranged from less than 0.010 to 0.027 mg/L with a median value of less than 0.010 mg/L. Phosphorus concentrations in the UTEN Valley and Ridge springs were less than concentrations in ground water from other NAWQA study units (table 4).

Bacteria

Bacterial, viral, and protozoan pathogens are among the most dangerous contaminants in drinking water. About 50 percent of the waterborne-disease outbreaks in this country since the early 1900s were caused by contaminated ground water that was untreated or inadequately treated. Most of these

outbreaks were caused by pathogenic (disease-causing) microorganisms (Yates and Yates, 1993). A common misconception is that untreated ground water is generally safe for consumptive use, and that most contaminants are removed as the water filters down through the soil. The soil does act as a natural filter for water percolating down through the ground, but this does not guarantee that ground-water supplies cannot become contaminated (Bickford and others, 1996).

Water samples from each spring were analyzed for two types of fecal-indicator bacteria—*E. coli* and total coliform. Fecal-indicator bacteria are used to assess the quality of water because they are associated with the presence of several waterborne pathogens (Dufour, 1977). The concentration of fecal-indicator bacteria is a measure of water safety for body-contact recreation or for consumption. The presence of *E. coli* in water is direct evidence of fecal contamination from warmblooded animals and indicates the possible presence of pathogens (Dufour, 1977). For potable waters, the detection of as few as 4 total coliform col/100 mL, and the detection of 1 col/100 mL of *E. coli* warrant concern for public health (U.S. Environmental Protection Agency, 1986). *E. Coli* is one of the preferred fecal-indicator bacteria as predictors of swimming-associated gastroenteritis in marine and freshwater settings.

All of the springs sampled had fecal-indicator bacteria present, indicating the possibility of fecal contamination. Total coliform values ranged from 10 to 1,900 col/100 mL (table 5), and *E. coli* values in the springs ranged from less than 1 to 660 col/100 mL. Of the 35 springs sampled, 91 percent of the springs had some level of *E. coli*, and all springs had total coliform present. Although private drinking-water supplies are not regulated, the presence of total coliform and *E. coli* in all of the springs sampled exceeded drinking-water standards for public water systems.

In comparison, bacteriological samples were collected at 30 randomly selected wells in similar land use and geological settings in the UTEN Valley and Ridge between September 1998 and February 1999 (Hampson and others, 2000). The samples from these wells had detections of *E. coli* in 9 wells (30 percent) ranging from 1 to 1,200 col/100 mL and total coliform at 11 wells (37 percent) ranging from 5 to 1,600 col/100 mL. These results indicate that these domestic and public water-supply wells are generally less susceptible to bacteriological contamination than are the springs.

Only one water sample was taken at each spring and well, representing water-quality conditions at the time of the sample collection. Bacteria levels can vary over time due to many factors, including rainfall and temperature variations, antecedent soil-moisture conditions, and land-use activities in the recharge area. Of 25 springs sampled in Kentucky, fecal coliform levels indicated seasonal variations of average monthly concentrations from about 70 to 300 col/100 mL. More than 90 percent of the Kentucky springs showed the presence of bacteria from May to June 1995 (O'Dell, 1996). Temporal variation in bacteria concentrations also were noted in ground-water samples in Bedford County in Middle Tennessee (Roman-Mas and others, 1991; Bennett, 1997). Bedford County has thin soils, open fractures, sinkholes, and rapid movement of contaminants in the subsurface. Agricultural activities such as applying manure, the variation of animal populations in feedlots or other livestock operations, as well as failing septic systems, are all potential sources of bacteriological contamination that are subject to temporal variations.

Pesticides

Pesticides were detected frequently at low concentrations (less than 0.01 µg/L) in water samples from springs in the UTEN Valley and Ridge (table 6). Six pesticides and 2 degradation byproducts were detected in samples from 35 springs in the UTEN Valley and Ridge (table 6); however, 71 other pesticides and 6 degradation byproducts were analyzed for but were not detected in any of the springs (table 7). Pesticides were not detected at 11 springs; whereas, 1 to 6 pesticides or degradation byproducts were detected at 24 springs (fig. 5). Of the 8 pesticides and degradation byproducts detected, 7 have at least one of the following established regulations or criteria: the U.S. EPA's MCL; health advisory level (HA-L); risk-specific lifetime dose (RSD) at a cancer risk level of 1 in 100,000; or the Canadian aquatic-life criterion (CALC) (Gilliom, 1999). Concentrations for all of the pesticides detected in the springs were below current drinking-water standards; some detections were below the LRL and were reported as estimated concentrations.

The most frequently detected pesticides in the UTEN Valley and Ridge spring samples (fig. 6, table 6) were atrazine (57 percent of springs), deethyl-atrazine (atrazine-degradation byproduct) (54 percent), tebuthiuron (31 percent), prometon (17 percent),

Table 5. Bacteriological results for springs in the Valley and Ridge Physiographic Province in the upper Tennessee River Basin

[<, less than]

Spring no.	Spring name	Total coliform colonies per 100 milliliters	<i>Escherichia coli</i> colonies per 100 milliliters
1	Ellis Spring at Ringgold, Ga.	50	6
2	Carson Spring near Ooltewah, Tenn.	19	2
3	Maynor Spring near Benton, Tenn.	640	23
4	McCaslan Spring near Tasso, Tenn.	260	20
5	Big Spring at Big Spring, Tenn.	21	3
6	Hawk Spring near Hillsview, Tenn.	570	250
7	Malone Spring near Niota, Tenn.	100	4
8	Ward Spring near Watts Bar, Tenn.	57	16
9	Reed Spring near Philadelphia, Tenn.	330	35
10	Pearson Spring at Maryville, Tenn.	130	7
11	Barnard Spring near Bacon Gap, Tenn.	220	4
12	Rocky Spring at Boyds Creek, Tenn.	30	3
13	Bailey Spring near Kodak, Tenn.	63	3
14	Unnamed Spring Number 3 to Scarboro Creek near Oak Ridge, Tenn.	120	19
15	Riley Spring near Dandridge, Tenn.	37	11
16	Hunter Spring near Halls Crossroad, Tenn.	1,900	52
17	Shetterly Spring near Clinton, Tenn.	510	3
18	Seaton Spring at Pleasant Hill, Tenn.	12	<1
19	Mitchell Spring near Talbott, Tenn.	200	110
20	Nelson Spring at Mill Creek Road at Mill Creek, Tenn.	230	13
21	Morelock Spring near Newmansville, Tenn.	63	6
22	Dodson Spring near Russellville, Tenn.	270	16
23	Jones Spring near College Park, Tenn.	1,600	1
24	Chalybeate Spring near Sulphur Springs, Tenn.	1,400	88
25	Ball Creek Spring near Tazewell, Tenn.	800	660
26	Mason Spring near Tazewell, Tenn.	35	3
27	Fall Branch Spring, Sneedville, Tenn.	12	1
28	Henderson Spring above Amis Chapel, Tenn.	220	17
29	Bright Spring near Mill Point, Tenn.	130	13
30	Cheek Spring near Jonesville, Va.	14	<1
31	Johnson Spring near Clinchport, Va.	78	11
32	Yellow Spring near Lindell, Va.	240	<1
33	Brickly Spring near Fort Blackmore, Va.	79	6
34	Seven Spring near Banners Corner, Va.	10	1
35	Cave Spring near Broadford, Va.	300	37

Table 6. Pesticides detected in springs in the Valley and Ridge Physiographic Province in the upper Tennessee River Basin

[LRL, laboratory reporting level; MCL, maximum contaminant level; HA-L, health advisory level; RSD, risk-specific lifetime dose at a cancer risk level of 1 in 100,000; CALC, Canadian aquatic-life criterion; µg/L, micrograms per liter; --, not reported; E, estimated value]

Pesticides and degradation byproducts	Type	LRL (µg/L)	Human and Aquatic Health criterion ^a (µg/L)	Estimated pounds applied in 1992 ^b	Percent (and number) of samples with detections	Percent (and number) of samples above 0.01 µg/L	Maximum concentration (µg/L)
Alachlor	Herbicide	0.0024	2.0 (MCL)	31,100	3 (1)	0	E 0.003
Atrazine	Herbicide	0.007	3.0 (MCL) 1.8 (CALC)	88,160	57 (20)	20 (7)	0.063
Deethylatrazine	Herbicide degradate	0.006	--	--	54 (19)	17 (6)	0.018
Metolachlor	Herbicide	0.013	70 (HA-L)	35,200	11 (4)	3 (1)	0.021
<i>p,p'</i> -DDE	Insecticide degradate	0.0025	1 (RSD)	--	3 (1)	0	E 0.001
Prometon	Herbicide	0.015	100 (HA-L)	--	17 (6)	3 (1)	0.023
Simazine	Herbicide	0.011	4 (MCL) 10 (CALC)	18,100	9 (3)	0	E 0.006
Tebuthiuron	Herbicide	0.016	500 (HA-L) 1.6 (CALC)	--	31 (11)	20 (7)	0.539

^a From Gilliom, 1999, ^b From Majewski, 1997

simazine (9 percent), and metolachlor (11 percent). The remaining pesticide and degradation byproducts (alachlor and *p,p'*-DDE) were detected only once. Five pesticides or degradation byproducts were detected above a common threshold of 0.01 µg/L: atrazine (20 percent of springs), tebuthiuron (20 percent), deethylatrazine (17 percent), prometon (3 percent), and metolachlor (3 percent) (table 6).

Pesticides were detected more frequently in the UTEN Valley and Ridge springs than in 1,848 groundwater samples from wells in similar NAWQA studies across the Nation (fig. 6) (Kolpin, 2000). Atrazine and deethylatrazine were detected at least twice as frequently in the UTEN Valley and Ridge springs than nationwide; however, concentrations were less than 0.1 µg/L in all water samples in the UTEN Valley and Ridge springs, whereas about 4 percent of samples nationwide exceeded 0.1 µg/L. Tebuthiuron was detected in the UTEN Valley and Ridge springs at substantially higher frequencies at all screening levels. Prometon and metolachlor were detected in the UTEN Valley and Ridge springs more frequently than nationwide at levels below 0.01 µg/L, and at similar detec-

tion frequencies above 0.01 µg/L. Alachlor and simazine also were detected more frequently in the UTEN Valley and Ridge springs at levels below 0.01 µg/L, but a greater frequency was detected nationwide at levels above 0.01 µg/L. Concentrations of *p,p'*-DDE were found at similar detection frequencies in the UTEN Valley and Ridge springs and nationwide.

For comparison, pesticide samples also were collected at 30 randomly selected wells in similar land-use and geological settings in the UTEN Valley and Ridge between September 1998 and February 1999 (Hampson and others, 2000). Water samples from these wells contained pesticides similar to those detected in the springs but at lower detection frequencies. Atrazine, deethylatrazine, tebuthiuron, prometon, metolachlor, and simazine were all detected less frequently in the UTEN wells than in the springs, but the detection frequency was higher for wells than the detection frequency for other NAWQA studies.

Results from 20 NAWQA study units, from 1993 to 1995, indicate that the greatest frequency of herbicide detections in major aquifers occurred in

Table 7. Pesticides not detected in springs in the Valley and Ridge Physiographic Province in the upper Tennessee River Basin

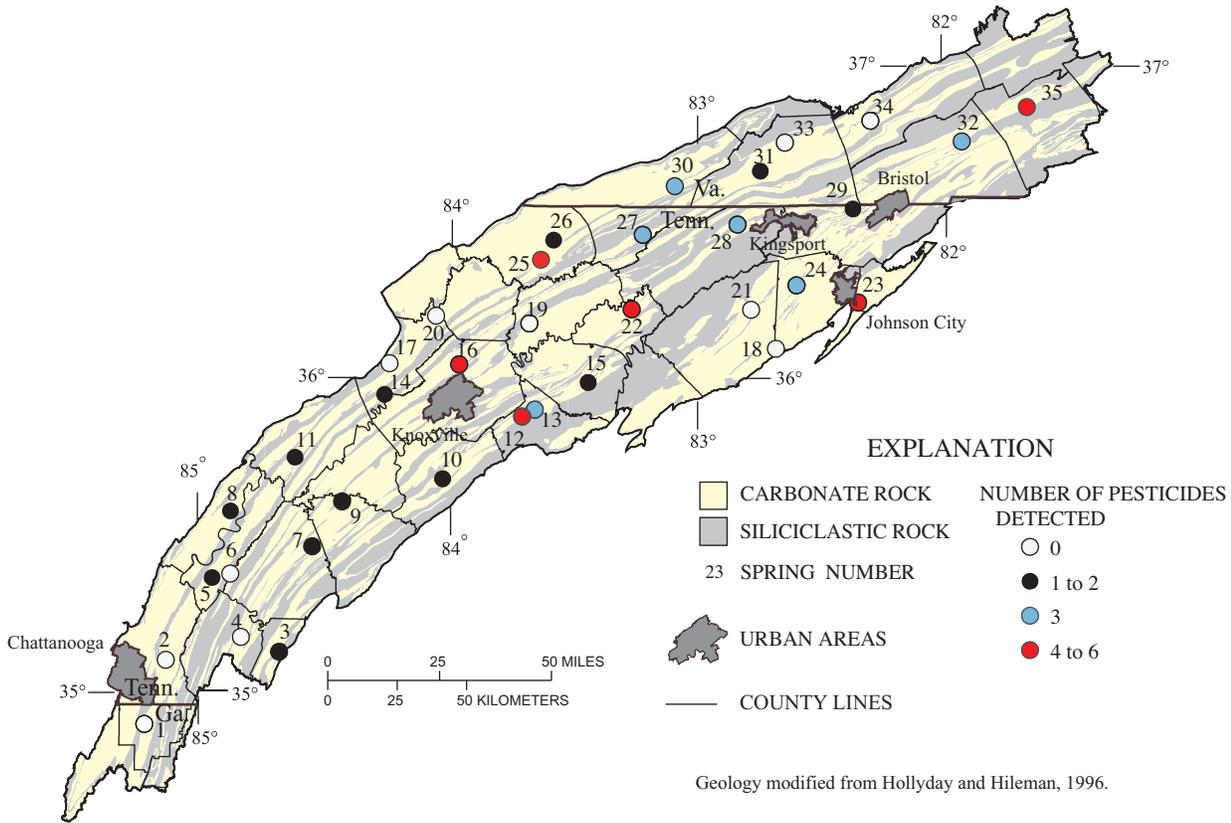
[LRL, laboratory reporting level, in micrograms per liter; <, less than; --, not reported]

Pesticide	Type	LRL	Estimated pounds applied in 1992 ^a
2,4-D	Herbicide	0.110	33,400
Pebulate	Herbicide	0.0016	23,900
Pendimethilin	Herbicide	0.010	20,700
Butylate	Herbicide	0.002	18,800
Cyanazine	Herbicide	0.018	11,200
Napropamide	Herbicide	0.007	9,500
Dicamba	Herbicide	0.043	4,370
2,4-DB	Herbicide	0.100	4,060
Diuron	Herbicide	0.056	2,540
Trifluralin	Herbicide	0.009	2,500
Terbacil	Herbicide	0.034	1,790
Triclopyr	Herbicide	0.070	1,540
Metribuzin	Herbicide	0.006	1,980
Bentazon	Herbicide	0.035	1,310
Linuron	Herbicide	0.021	860
Oryzalin	Herbicide	0.028	710
Ethalfuralin	Herbicide	0.009	370
Norflurazon	Herbicide	0.042	300
Chloramben, methylester	Herbicide	0.140	280
Dichlobenil	Herbicide	0.049	170
Bromoxynil	Herbicide	0.070	<10
MCPA	Herbicide	0.080	<10
2,6-Diethylaniline	Herbicide	0.0017	--
	degradate		
2,4,5-T	Herbicide	0.040	--
2,4,5-TP (silvex)	Herbicide	0.025	--
Acetochlor	Herbicide	0.0041	--
Acifluorfen	Herbicide	0.050	
Benfluralin	Herbicide	0.010	--
Bromacil	Herbicide	0.090	--
Clopyralid	Herbicide	0.420	--
Dacthal (DCPA)	Herbicide	0.003	--
Dacthal, mono acid	Herbicide	0.070	--
Dichlorprop	Herbicide	0.050	--
Dinoseb	Herbicide	0.090	--
DNOC	Herbicide	0.250	--
EPTC	Herbicide	0.002	--
Fenuron	Herbicide	0.070	--
Fluometuron	Herbicide	0.060	
Linuron	Herbicide	0.021	--
MCPB	Herbicide	0.130	--

Table 7. Pesticides not detected in springs in the Valley and Ridge Physiographic Province in the upper Tennessee River Basin—Continued

Pesticide	Type	LRL	Estimated pounds applied in 1992 ^a
Methiocarb	Herbicide	0.070	--
Molinate	Herbicide	0.0016	--
Neburon	Herbicide	0.017	--
Picloram	Herbicide	0.090	--
Propachlor	Herbicide	0.010	--
Propanil	Herbicide	0.011	--
Propham	Herbicide	0.090	--
Propzamide	Herbicide	0.0041	--
Thiobencarb	Herbicide	0.0048	--
Triallate	Herbicide	0.0023	--
Chlorpyrifos	Insecticide	0.005	54,300
Carbaryl	Insecticide	0.024	20,700
Carbofuran	Insecticide	0.020	12,900
Aldicarb	Insecticide	0.210	7,530
Methomyl	Insecticide	0.020	6,030
Ethoprophos	Insecticide	0.005	5,900
Methyl parathion	Insecticide	0.006	2,260
Diazinon	Insecticide	0.005	1,970
Disulfoton	Insecticide	0.021	1,950
Propargite	Insecticide	0.023	1,820
Terbufos	Insecticide	0.017	1,360
<i>cis</i> -Permethrin	Insecticide	0.006	1,200
Malathion	Insecticide	0.027	930
Oxamyl	Insecticide	0.020	520
Phorate	Insecticide	0.011	440
Fonofos	Insecticide	0.0027	230
Lindane	Insecticide	0.004	10
1-Naphthol	Insecticide degradate	0.007	--
3-Hydroxycarbofuran	Insecticide degradate	0.110	--
Aldicarb sulfone	Insecticide degradate	0.200	--
Aldicarb sulfoxide	Insecticide degradate	0.020	--
Methyl azinphos	Insecticide	0.050	--
Dieldrin	Insecticide	0.0048	--
HCH, alpha	Insecticide degradate	0.0046	--
Parathion	Insecticide	0.007	--
Propoxur	Insecticide	0.120	--
Chlorothalonil	Fungicide	0.130	9,800

^a From Majewski, 1997



Base from U.S. Geological Survey digital data, 1:250,000; and U.S. Department of Commerce 1:100,000, 1993

Figure 5. Pesticides detected in springs in the Valley and Ridge Physiographic Province in the upper Tennessee River Basin.

vulnerable settings. The three aquifers with the highest frequency of detections were (1) the Platte River Alluvial aquifer, a shallow aquifer overlain by permeable sandy soils, in the Central Nebraska Basins (92.6 percent); (2) the Upper Floridan aquifer, a limestone formation in which flow rates are high, in the Appalachian-Chattahoochee-Flint River Basin (80 percent); and (3) a shallow limestone aquifer in the Lower Susquehanna River Basin (83 percent) (U.S. Geological Survey, 1999). In comparison, the UTEN Valley and Ridge springs had a 69-percent herbicide detection frequency. The UTEN Valley and Ridge is underlain by weathered limestone and dolomite formations and is equally vulnerable to contamination, but the UTEN area is subject to less intense agricultural production than the three aforementioned aquifers.

The two most commonly detected pesticides in the UTEN Valley and Ridge springs are atrazine and tebuthiuron. Atrazine is an herbicide used to control broadleaf and grassy weeds on corn, sorghum, Christ-

mas trees, and other crops. Atrazine also is used as a nonselective herbicide on industrial and fallow lands. Atrazine has been the most extensively used pesticide in the United States since the early 1970s and has been the most frequently detected pesticide reported in ground water during many previous state, regional, and national studies (Kolpin and others, 1998). Atrazine and its degradation byproducts also are the most commonly detected pesticide compounds in the surface waters of the UTEN, present at over 90 percent of the surface-water sites (M.W. Treece, U.S. Geological Survey, written commun., 2001).

Tebuthiuron is a broad-spectrum, nonselective, soil-activated herbicide that acts by inhibiting photosynthesis. Tebuthiuron is used to control broadleaf and woody weeds, grasses, and brush on pasture and rangeland and on a variety of nonfood crop sites including industrial areas, rights-of-way, fence lines, hedgerows, and uncultivated areas. Primary uses include rangeland and near railroads and other industrial facilities (U.S. Environmental Protection Agency,

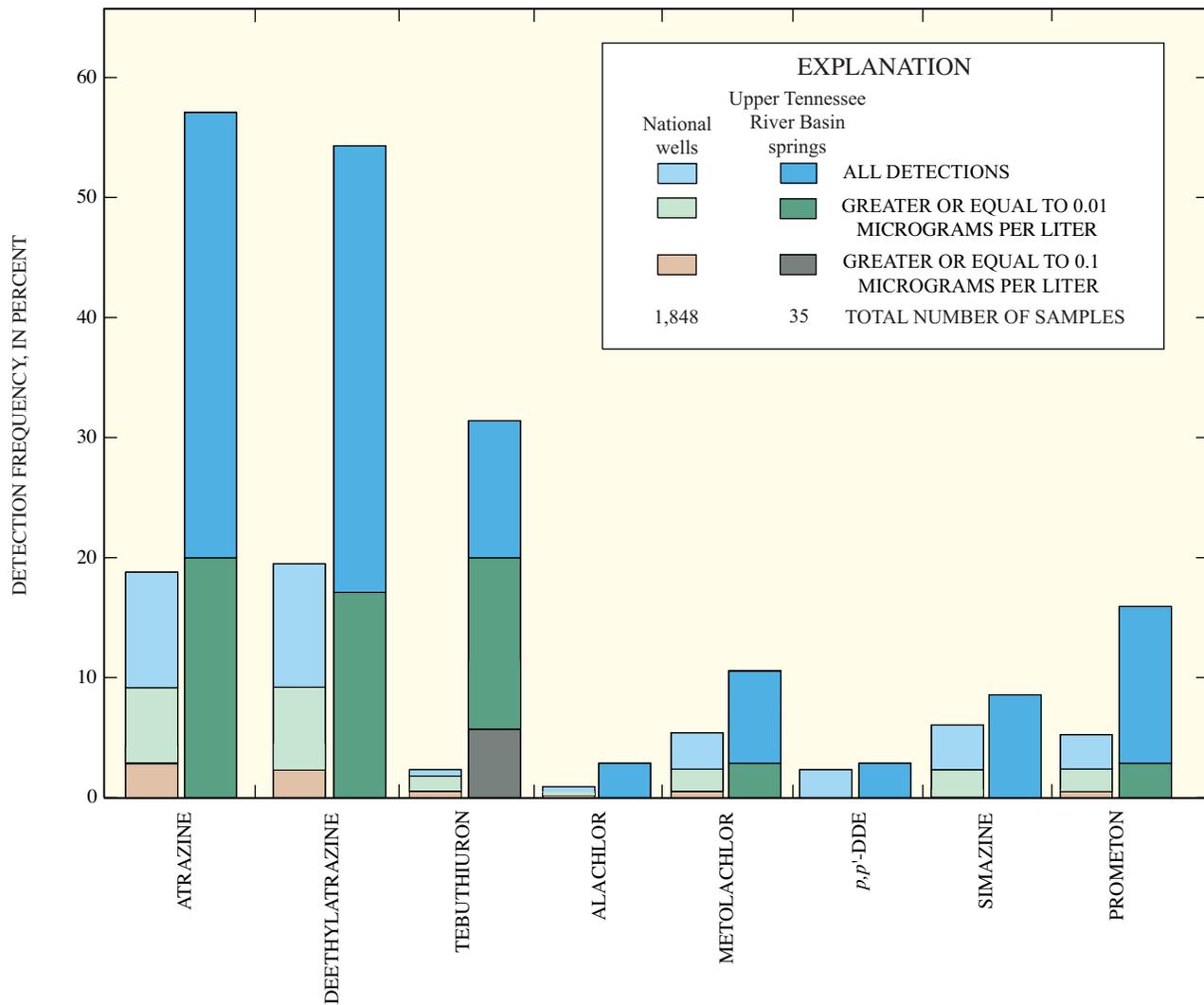


Figure 6. Detection frequency of pesticides for springs in the Valley and Ridge Physiographic Province in the upper Tennessee River Basin and National Water-Quality Assessment Program wells nationwide from 1993 to 1998.

1994). Tebuthiuron is highly persistent and easily moves with moisture through the soil. Photodecomposition of tebuthiuron is negligible, as is volatilization (or evaporation from the soil surface). Tebuthiuron is readily absorbed through roots and translocated to other plant parts (Extension Toxicology Network, 1996).

Volatile Organic Compounds

Volatile organic compounds include components of petroleum products, metal degreasers, solvents, refrigerants, cleaning compounds, and agricultural fumigants. VOCs also are present in fuels and exhaust from fuel combustion. Direct industrial

and wastewater discharges into surface water and the atmosphere and accidental fuel and oil spills are likely sources of VOCs in ground water. VOCs in rainfall may originate from vehicle and industrial emissions. Storm-water runoff is another possible source of VOC detections in springs. Relating land uses to specific compounds is difficult because of the varied and widespread use of VOCs, as well as the possibility of atmospheric deposition.

Twenty-two VOCs (table 8) were detected in water samples from 30 of the 35 springs (fig. 7), with as many as 9 VOCs detected at 2 springs. Most of the VOC detections were below the LRL (table 8). The most frequently detected VOC was chloroform, which was detected in 20 springs and exceeded the LRL at

Table 8. Summary of volatile organic compound detections for 35 springs in the Valley and Ridge Physiographic Province in the upper Tennessee River Basin

[Units are in micrograms per liter; --, no applicable standard; MCL, maximum contaminant level; HA-L, health advisory level; LRL, laboratory reporting level; *, quality-assurance blanks showed a possibility of contamination for these constituents]

Constituent	Total number of detections (Number of detections above LRL)	Laboratory reporting level (LRL)	Maximum concentration	Lifetime HA-L ^{a,b}	MCL ^{a,c}
Chloroform	20 (5)	0.052	1.320	--	100 ^d
Methyl chloride	18 (0)	0.254	0.09	3	--
Styrene *	12 (0)	0.042	0.037	100	100
Tetrachloroethene	11 (1)	0.038	0.284	--	5
Toluene *	7 (4)	0.038	0.125	1,000	1,000
1,1,1-Trichloroethane	7 (2)	0.032	0.229	--	200
Trichloroethene	5 (1)	0.038	0.509	--	5
1,1-Dichloroethane	3 (2)	0.066	0.576	--	--
Bromodichloromethane	3 (1)	0.048	0.080	--	100 ^d
<i>cis</i> -1,2-Dichloroethene	2 (1)	0.033	0.08	--	70
Carbon disulfide	2 (0)	0.08	0.020	--	--
Dichlorodifluoromethane	2 (0)	0.096	0.04	1,000	--
1,4-Dichlorobenzene	2 (0)	0.05	0.009	--	4
Freon -113	2 (0)	0.032	0.02	--	--
Metapara xylene	1 (0)	0.064	0.018	10,000 ^e	10,000 ^e
tert-Pentyl methyl ether	1 (1)	0.112	0.17	--	--
Methyl <i>tert</i> -butyl ether (MTBE)	1 (1)	0.112	9.51	20	--
1,1-Dichloroethene	1 (1)	0.044	0.06	--	7
Benzene	1 (0)	0.032	0.010	--	5
Chloroethane	1 (0)	0.12	0.07	--	--
Diisopropyl ether	1 (0)	0.098	0.05	--	--
Ethylether	1 (0)	0.17	0.061	--	--

^a U.S. Environmental Protection Agency (1996) drinking-water regulations and health advisories.

^b Drinking-water lifetime health advisory level (HA-L). The concentration of a chemical in drinking water that is not expected to cause any adverse noncarcinogenic effects over a lifetime of exposure, with a margin of safety.

^c Maximum contaminant level (MCL). Maximum permissible level of a contaminant in water which is deliverable to any user of a public water-supply system (U.S. Environmental Protection Agency, 1996)

^d Total for all trihalomethanes combined cannot exceed 100 micrograms per liter.

^e Guidelines are for total xylene.

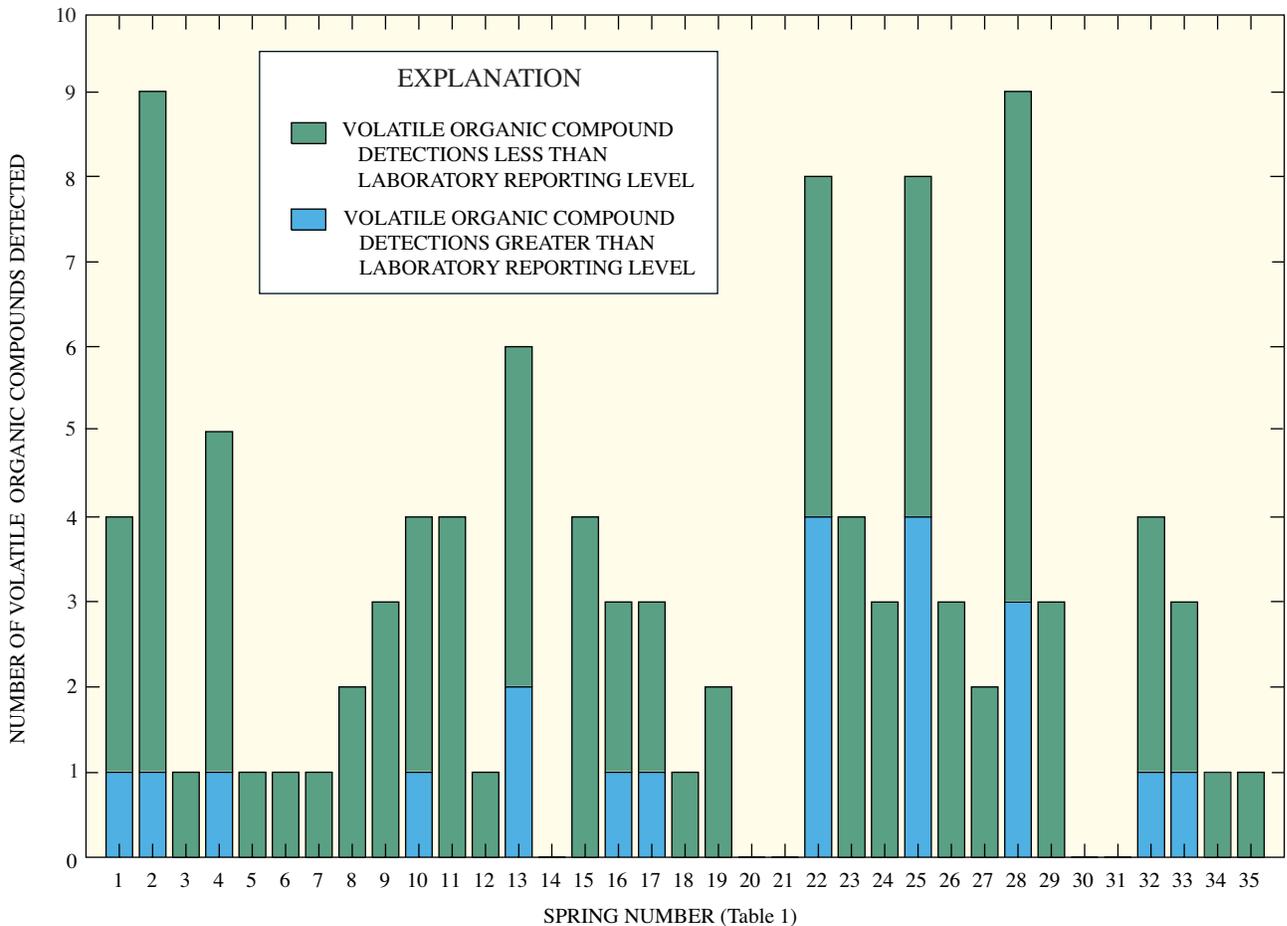


Figure 7. Number of volatile organic compounds detected in springs in the Valley and Ridge Physiographic Province in the upper Tennessee River Basin.

5 springs (table 8). Other frequently detected VOCs were methyl chloride (18 detections), tetrachloroethene (11 detections), 1,1,1-trichloroethane (7 detections), and trichloroethene, (5 detections) (table 8). Styrene and toluene also were detected frequently, but the validity of those results is suspect because these compounds were detected in blank samples.

None of the VOCs detected in the UTEN Valley and Ridge springs exceeded established drinking-water standards or advisories (table 8). Detection frequencies for VOCs above 0.2 µg/L in the UTEN are similar to the detection frequencies for ground water nationwide (fig. 8) (Squillace and others, 1999; Michael J. Moran, U.S. Geological Survey, written commun., 2001). The detection frequencies for VOCs in the UTEN Valley and Ridge springs generally are between the national detection frequencies for wells in urban settings and wells in rural settings (fig. 8). Land

use in the area surrounding the springs includes a mixture of urban, agricultural, and forest.

SUMMARY

Water-quality data for nutrients, fecal-indicator bacteria, pesticides, and volatile organic compounds (VOCs) were collected at 35 randomly selected springs in the UTEN Valley and Ridge Physiographic Province. The karst hydrology in the carbonate rock units of the UTEN study area can provide rapid pathways for contaminants to enter the ground water by direct runoff through sinkholes and other karst features.

Samples from the springs were analyzed for nutrients including nitrate, ammonia, ammonia plus organic nitrogen, total phosphorus, and orthophosphate. Nutrient concentrations in the springs generally were less than 2 mg/L. Nitrate was the most

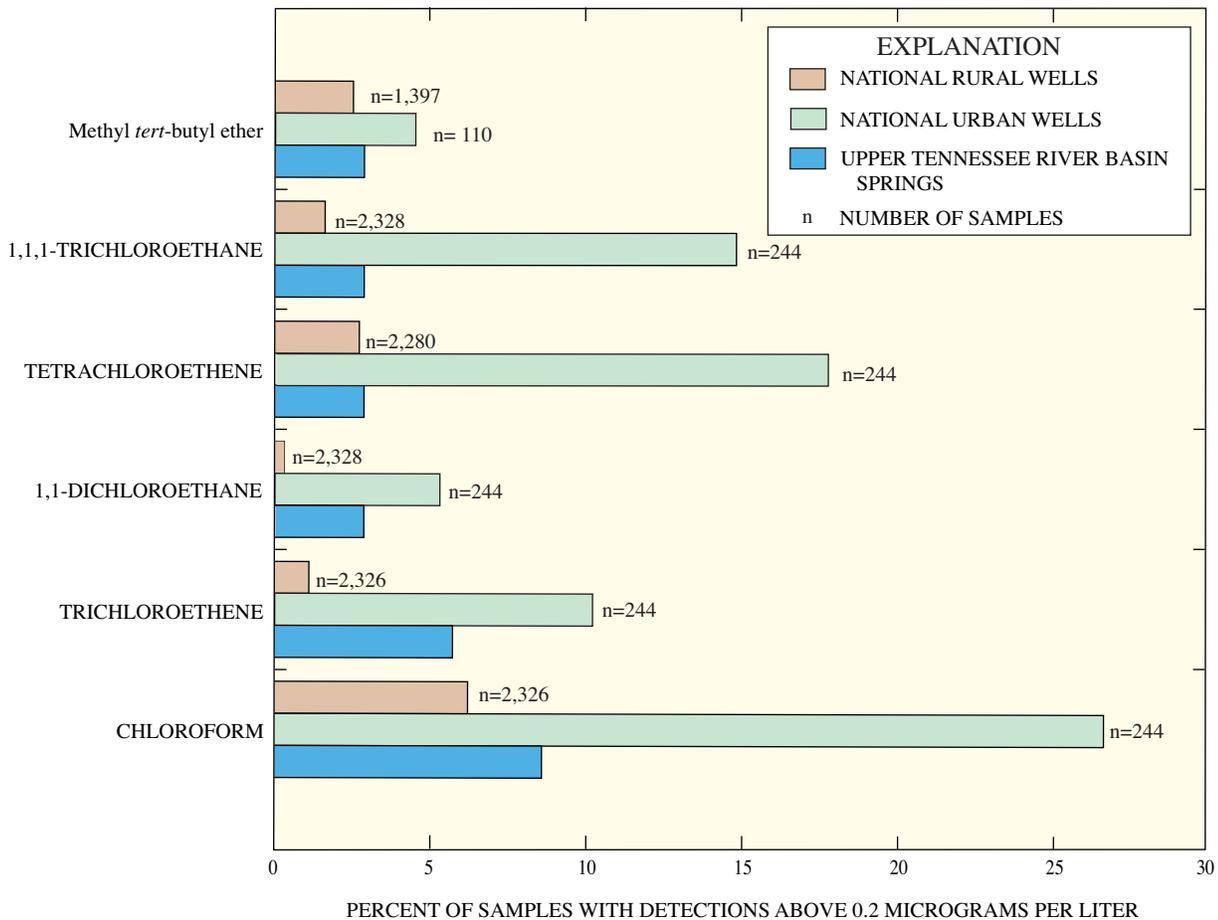


Figure 8. Volatile organic compound detections above 0.2 micrograms per liter for springs in the Valley and Ridge Physiographic Province in the upper Tennessee River Basin and National Water-Quality Assessment Program wells in rural and urban settings nationwide from 1993 to 1998.

commonly detected nutrient species and ranged from 0.091 to 2.17 mg/L, with a median concentration of 1.16 mg/L. The median nitrate concentration for the springs was greater than median values found in ground water for other similar NAWQA aquifer studies. During other studies in the southeastern and northeastern United States, higher nitrate levels have been detected in springs in agricultural areas compared to springs in other land-use settings, and higher nutrient levels have been detected in springs compared to wells in similar land-use settings.

Bacteriological contamination of waters in karst settings is of particular concern. Almost half of the springs in the study area were used as untreated drinking-water supplies, either by directly pumping from the spring or as roadside filling sites. Fecal-indicator bacteria were detected at all springs, with total coliform ranging from 10 to 1,900 col/100 mL

and *E. coli* ranging from less than 1 to 660 col/100 mL. All springs sampled had bacteriological levels that warrant concern. Although private drinking-water supplies are not regulated, the presence of total coliform and *E. coli* in all of the sampled springs exceeded drinking-water standards for public water systems. The high concentrations detected in some springs can be a health risk.

Pesticides were detected frequently at low concentrations in the springs. Eight pesticides or degradation byproducts were detected in samples from springs in the UTEN Valley and Ridge. Eleven springs had no pesticides detected. The remaining 24 springs had 1 to 6 pesticides or degradation byproducts detected. All pesticide concentrations were below their respective MCLs. The detection frequency for a number of pesticides was greater than the detection frequency for

ground-water samples from wells in similar NAWQA studies.

Twenty-two VOCs were detected in water samples from 30 of the 35 springs, with as many as 9 different VOCs detected at 2 springs. Concentrations of VOCs were less than their respective MCLs, and the detection frequency above 0.2 µg/L for the most commonly detected compounds ranged between concentrations for wells in urban settings and wells in rural settings for similar NAWQA ground-water studies. The setting for the springs was a mixture of urban and rural land use; therefore, the VOC results of the UTEN study are consistent with the national results.

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